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Scheduling procedures for a family practice doctor's office.

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SCHEDULING PROCEDURES FOR A FAMILY PRACTICE DOCTOR’S OFFICE

By

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A CONSIDERATION OF SCHEDULING PROCEDURES AS APPLIED TO FAMILY PRACTICE DOCTOR'S OFFICES

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A Thesis Approved On

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A special thanks to Jeffersontown Family Practice and Dr. James Wright for opening their facility to my research.

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ABSTRACT

In order to allow quality healthcare to be available to more people, healthcare must be as affordable as possible. Ideally this will be done through the elimination of the waste that is built into the current healthcare system. One area that is ready for waste reduction is the manner in which family practice doctors' offices and hospitals schedule patients. Despite hospitals being incredibly sophisticated and employing very intelligent individuals, their scheduling is often very old fashioned and does not take into account walk-in patients or no-show patients.

Fortunately, some more advanced scheduling methods have been developed. One of these scheduling methods is overbooking. Overbooking is when an office schedules more patients than it can serve in order to compensate for the chance that a patient will not honor their appointment. Unfortunately overbooking usually doesn't consider walk-in patients (which are becoming increasingly common). The research herein shows that scheduled patients are preferred to walk-in patients. A schedule consisting entirely of walk-in patients should expect an 80% increase in wait time over an entirely scheduled patient base. This occurs

despite both systems helping the same number of patients. As such, doctor's offices should incentivize their patients to schedule appointments rather than arrive unannounced.

This study also shows that as the no show rate of schedule patients increases, so does the expected wait time by the patients (when the office is using the overbooking scheduling method). For this simulation built in this study (an overbooking simulation), there will be an 18% decrease in patient wait time if a doctor can move from 10% no-shows to 0% no-shows. Overbooking helps maintain a high utilization in offices with high no-show rates, but the best system is one where all the patients honor their appointments. A more scientific approach to scheduling in doctor's offices will allow doctors to spend more time helping patients: a good thing for doctors and patients alike.

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NOMENCLATURE

DOE	=	Design of Experiment
GDP	=	Gross Domestic Product
JFP	=	Jeffersontown Family Practice

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I. INTRODUCTION

This study will look into how overbooking reacts to the inclusion of walk-in patients in terms of patient wait time, doctor utilization, and office overtime. This study will also look into how overbooking adjusts to accommodate different no-show rates. To accomplish this, the next chapters will begin with a familiarization of the research currently done in the field of scheduling in healthcare. These chapters will look into the current trends in the healthcare industry: particularly trends in the healthcare industry's capacity and costs. The next section will compare and contrast several common scheduling practices; traditional, the carve-out model, the advanced access model, and overbooking. None of these scheduling methods consider walk-in patients, so they will be added to the model. With all the background research in place, the study's simulation will be built, dissected, and explained. The final sections will run the simulation under various circumstances and draw conclusions.

II. JEFFERSONTOWN FAMILY PRACTICE

In order to ensure that a doctor's office was properly represented throughout the study, an actual doctor's office was visited and used throughout the research. This doctor's office was Jeffersontown Family Practice (JFP) which is located on the east end of Louisville, KY. JFP is a family practice and primarily helps patients with physicals, checkups, and common illnesses. Jeffersontown Family Practice is a very typical doctor's office. It consists primarily of six doctors (each with a nurse to help), several shared nurses for specific tasks, and a small shared business staff. Each doctor typically works four days a week from 8am until 5pm during which they will see somewhere between 26 and 32 patients. Most patients are given 15 minute appointments, but once or twice a day a patient is given a full physical. These require a full hour. The office was very kind in allowing complete access to their processes to the study. JFP was observed throughout the fall of 2010 and spring of 2011. As such, all the conclusions drawn by this study could be checked for accuracy by comparing them to JFP.

III. NO-SHOWS IN HEALTHCARE

Currently, the healthcare industry is in a very unique place. There is talk of government intervention. Most recently, President Obama signed the Patient Protection and Affordable Care Act (Stolberg, 2010). This act reforms private insurance practices, especially regarding the manner in which insurance companies treat those with preexisting conditions (Stolberg, 2010). This act became law on March 23rd, 2010.

Industrial Engineers are beginning to work more with doctors and hospitals. New treatments are being researched faster than ever. Within this exciting period, it is increasingly important to keep basic healthcare available to as many people as possible. This is best done by lowering costs through the elimination of waste. One form of waste is waiting time. Patients can spend hours waiting for doctors and doctors can spend time waiting for patients (viewed as idle time). Part of this problem is caused by the prevalence of no-show and walk-in patients.
Fortunately, there are several methods that have been

developed to mitigate the costs brought on by these kinds of patients.

A. Evidence of the Need for More Hospital Capacity

America needs more medical care capacity. Demand for medical services will increase as the baby boomer generation moves into its golden years. Those born between 1946 and 1964 make up 28% of the population of the United States. As this portion of society reaches its golden years, more baby boomers will be entering the healthcare system. The problem is compounded when one considers that much of the nursing community belongs to the baby boomer population. The nurses of this population segment will be retiring just as they begin to need the healthcare system. (Atchison, 2010)Demand for healthcare will rise and the supply will be decreasing.

Demand will also increase as Americans become more obese. The expected spending of an individual increases as he/she gains weight: see Figure 1. As spending increases, so does the number of patients entering the healthcare system, thus increasing demand ("US Congress," 2008, 10).

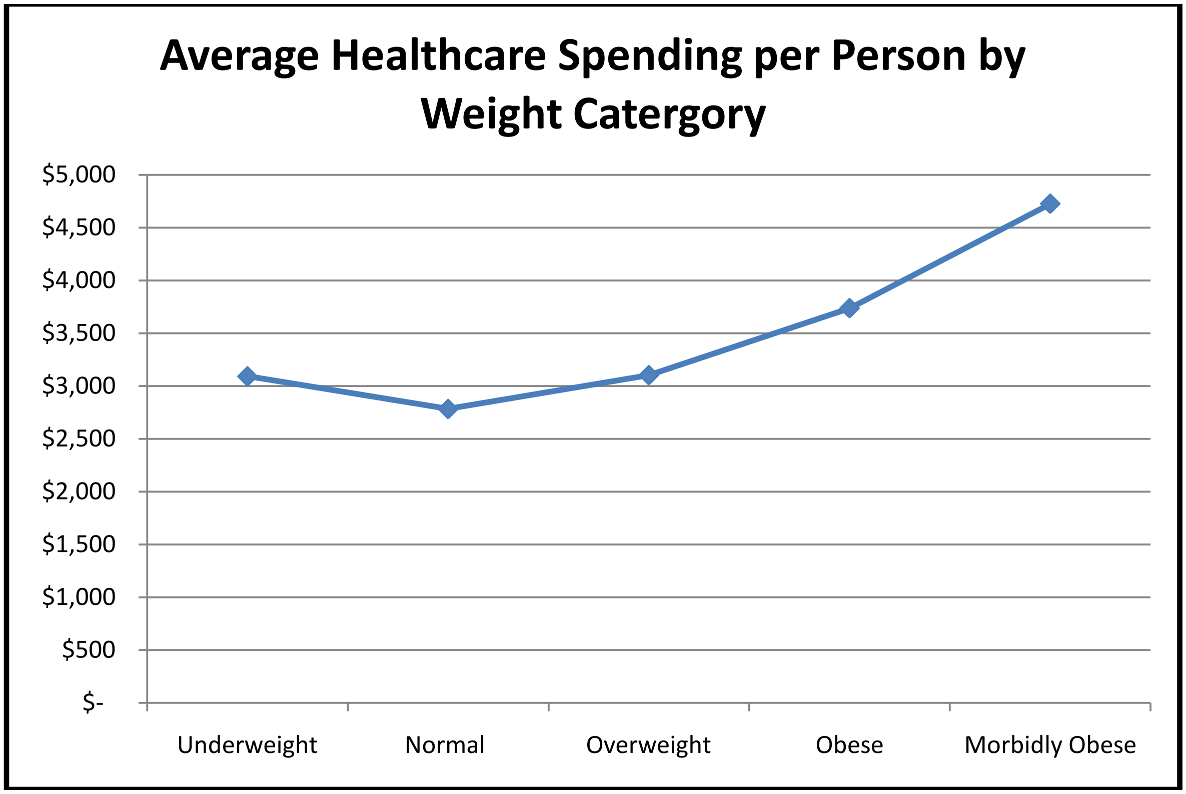
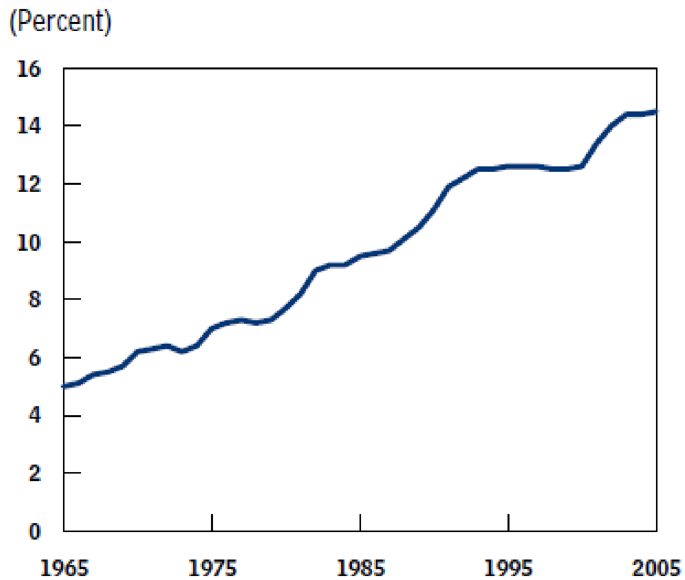


FIGURE 1 - Average Healthcare Expenses in 2001 Divided into Weight Categories ("US Congress," 2008, 10)

Patients can also expect to spend more time in the healthcare system than twenty years ago. Rising medical lawsuits have forced general practice doctors to send more and more patients to specialists. This "defensive medicine" extends the amount of time a patient spends in the healthcare system and increases the number of required visits per patient ("US Congress," 2008, 11).



Source: Congressional Budget Office based on data on spending on health services and supplies, as defined in the national health expenditure accounts, maintained by the Centers for Medicare and Medicaid Services.

Note: Spending amounts are adjusted for inflation using the gross domestic product implicit price deflator from the Bureau of Economic Analysis.

FIGURE 2 - Total Spending on Health Care as a Percentage of GDP ("US Congress," 2008, 4)

When demand rises and supply falls, the patient's time in system will increase, ceteris paribus. In this situation, hospitals will fill with patients. Evidence of this is already available. Figure 2 ("US Congress," 2008, 4) shows that healthcare's portion of the GDP has steadily risen since 1965. Studies have shown that when patients are denied access to outpatient services, they tend to go to higher cost providers, such as hospitals (Laganga and Lawrence, 2007). Furthermore, the number of non-urgent emergency room visits is currently at 40% and rising

(Murray, 2003). Immediate care centers are rising in popularity and perform many of the same functions as a family practice (Britt, 2009). If situations remain unchanged, either the number of healthcare facilities must increase or the capacity of each facility must increase.

B. Evidence of the Prevalence of No-Shows

In this time of excess healthcare costs and limited healthcare capacity, the costs associated with patient "no-shows" become increasingly relevant. A patient no-show is a situation where a patient makes an appointment with his/her doctor, but does not arrive for the appointment. No-show rates can vary widely depending on the patient base that the doctor serves. The most significant factor effecting no-show rates is the amount of time between scheduling the appointment and the appointment itself. Other statistically significant factors effecting no-show rates are diagnosis, demographic data, geography, weather, and current financial situation of the patient (Vozenilek, 2009). Even considering this data however, the no-show rates at practices vary widely and can range from as little as 3% to as much as 80% (LaGanga & Lawrence, 2007, 252). The nationwide no-show rate is expected to be somewhere between 20 and 40% of all appointments made (Vozenilek, 2009). This means, that if no-shows could be either eliminated or compensated for internally, then the effectiveness of hospital recovery upon usage would increase dramatically while decreasing costs for all patients.

For example, suppose that a doctor can provide 32 fifteen minute appointments in a given day. It costs his practice $3,200 dollars to stay open for a day once one considers salaries and building costs. If the doctor has an expected no-show rate near the national average of 33% then he must charge patients (and their insurance companies) $150 each on average in order to break even. Meanwhile, if everyone arrived for their appointments on time, the doctor would only have to charge $100 dollars while more people gain access to healthcare!

Many politicians are working tirelessly to find ways to simultaneously increase access to healthcare and decrease the cost. This is one way to make it possible. There is a large amount of financial incentive for decreasing for the no-show rate or compensating for no-show patients.

C. Causes for No-Shows

Taiichi Ohno in his Toyota Production System says that problems should be solved at the source (Ohno, 1988). As such, Toyota uses its "5 Why's" tactic to solve problems at the root rather than to solve the symptoms (Ohno, 1988). With this in mind, what causes no-shows? What makes a patient not arrive for their appointment? Research shows that it is a combination of forgetfulness and the patient's individual mentality toward appointments.

According to the research by Ayten Turkcan, the most common reason for a patient not arriving for appointments is simple forgetfulness. Turkcan's research finds that the more time there is between the time of scheduling the appointment and the appointment itself, the greater the likelihood of a no-show. He notes a particular drop-off at one week. A patient that is given an appointment that is less than a week away is more likely to show than a patient who books six months in advance. Jeffersontown Family Practice noticed this phenomenon and installed a computer to call and remind patients of their appointments a few days beforehand. Consequently, they saw a quick drop in no-shows (Vozenilek, 2009).

Turkcan also mentions "historical data, diagnosis, demographic data, geography, lead time, and weather" as other factors that may cause a patient to not arrive for their appointment. These factors imply that some patients simply take their appointments less seriously than others. Some patients work harder to keep appointments. The best patients will overlook poor weather, ailing health and long drives to visit their doctor on time. Unfortunately for scheduling, the patient's individual mentality toward the seriousness of appointments is beyond the control of the family doctor (Vozenilek, 2009).

D. Costs Associated with No-Shows

No-shows cost everyone in the healthcare system, even those who always show up on time. Doctors may penalize patients by charging a small fee for not showing, but the fee rarely covers the entire expense of the patient's absence. For example, Jeffersontown Family Practice charges the patient a $10 penalty fee for not showing up to an appointment. Unfortunately many of the costs created by no-shows are hidden and difficult to quantify.

Consider the costs of a patient not showing up to the doctor's office. Despite the patient not arriving, the doctor must still pay for the building and equipment for the extent of the planned visit. When the patient does not arrive, the office must continue to heat the building, turn on the lights, etc. More hidden, the doctor must cover the loss of capital throughout the visit. The exact cost of this depends on the amount of capital invested and the expected rate of return. Table I shows the expected loss from a fifteen minute appointment due to interest on capital. A single doctor's office costing $500,000 (approximate cost/doctor at Jeffersontown Family Practice) would cost the doctor $3.61 for every patient that doesn't show up for a 15 minute appointment (at 6% rate of return).

TABLE I

COST DUE TO CAPITAL INVESTMENT PER 15 MINUTES

	Expected Rate of Return							
Amount invested per doctor (thousands)	**3%**	**4%**	**5%**	**6%**	**7%**	**8%**	**9%**	**10%**
$ 250	$0.90	$1.20	$ 1.50	$ 1.80	$ 2.10	$ 2.40	$ 2.70	$ 3.00
$ 500	$1.80	$2.40	$ 3.00	**$ 3.61**	$ 4.21	$ 4.81	$ 5.41	$ 6.01
$ 750	$2.70	$3.61	$ 4.51	$ 5.41	$ 6.31	$ 7.21	$ 8.11	$ 9.01
$1,000	$3.61	$4.81	$ 6.01	$ 7.21	$ 8.41	$ 9.62	$10.82	$12.02
$1,250	$4.51	$6.01	$ 7.51	$ 9.01	$10.52	$12.02	$13.52	$15.02
$1,500	$5.41	$7.21	$ 9.01	$10.82	$12.62	$14.42	$16.23	$18.03
$1,750	$6.31	$8.41	$10.52	$12.62	$14.72	$16.83	$18.93	$21.03
$2,000	$7.21	$9.62	$12.02	$14.42	$16.83	$19.23	$21.63	$24.04

The major cost to the healthcare provider is in the loss of salary. A family practice can have many professional employees on the staff. As of May 2009, a certified nurse practitioner's median salary is around $41,000 annually after benefits. This comes to about $5 per fifteen minutes. The median family practitioner will make over $29 per fifteen minutes ("Wage Estimates," 2009). Most general practitioners also share several overhead employees with other doctors. These employees handle answering phones, handing medical records, overseeing finances and such. These employees must be paid as well whether a patient arrives for their appointment or not.

The act of patients not showing creates several unseen costs as well. For one thing, under traditional scheduling, patients that make an appointment and do not show require just as much capacity as patients that arrive. This makes it more difficult for patients to schedule appointments on short notice. "When patients are denied access to outpatient services, they are often forced to use providers of last resort (such as hospitals) at a much higher cost to the community" (LaGanga & Lawrence, 2007). The no-show patient is forcing punctual patients to visit either walk-in clinics (run by nurse practitioners) or the costly emergency room. This unfortunate emergency room visit breaks continuity of care, which the medical community has proven to be highly beneficial (Goitein, 1990).

No-shows create another form of variation: sometimes patients arrive, sometimes they don't. The manufacturing sector has learned that an increase in variation will lead to the deterioration of quality. A doctor plagued with unexpected empty appointment slots, may begin helping patients for 18 minutes per 15 minute slot, so as not to have idle time. However, what if everyone does show up for a few hours? Though the waste will be well hidden, quality will suffer somewhere from the increase in variation in patient arrival (Montgomery, 2009).

When a patient doesn't arrive for their appointment, they create a series of costs that they don't pay for themselves. Some of these costs can be calculated—such as those imposed on the doctor's office. Other costs are hidden—such as those imposed on the healthcare system. The variation caused by no-shows will hurt quality and eventually tax the system further. It is fiscally necessary to devise and implement a method to either eliminate no-shows or compensate for them.

IV. SCHEDULING METHODS

Anytime there is a process, there is a scheduling method. The method may be as simple as letting the first people in the line go first: like at the grocery store checkout. The scheduling method could get much more complex. A variety of scheduling methods have been devised for appointment based systems. Each is appropriate in its own situation. The following are several methods that were devised for appointment based systems: they can all be used in doctor's offices, college advising centers, financial planning, or any other situation where people make appointments.

A. Traditional Method

The traditional method is the most natural method. If a person were to start making appointments without thinking about scheduling, this is the process they would choose. Fortunately, it is the best method if everything goes as desired. When making the schedule, appointments are placed as far apart as it takes to help an individual. Thus, if it takes 15 minutes to treat a patient, appointments are placed 15 minutes apart. All appointments are filled on a first come first serve basis. Under traditional scheduling, some systems can be booked for months in advance, such as high end hair salons. When it comes time to act upon the schedule, the patients or customers are served at the time of the appointment.

The traditional method for scheduling appointments makes several assumptions. These assumptions are reasonable for many businesses, but not all. First, this method assumes that process time is both known and reasonably constant. It also assumes that all appointments show up for their appointments and are punctual. For some lucky family practice offices, this may be the case; however, many offices continue to use the traditional method despite fluctuating service times and a high patient tardiness rate. In order to compensate for these two sources of variation, real world doctors may adjust their traditional scheduling method. One easy way to do this is to visit with the patient for less than the full length of the visit. A doctor may schedule four appointments an hour and visit each patient for an average of ten minutes. This maintains that traditional scheduling method while keeping the system running smoothly. Unfortunately, this decreases the doctor's utilization. The traditional method works well in situations with consistent service times, punctual patients and where patients are willing to make appointments far in advance (Murray & Berwick, 2003, 1035).

B. The Carve-Out Model

In the medical field a doctor can handle a variety of patient problems. It quickly becomes apparent that some patient's problems are more urgent than others. How will a patient with the flu see his doctor quickly if the doctor is busy for the next two months with regular checkups? By the time the sick patient can see the doctor, they will either have gotten better or have visited the hospital emergency room. With the goal of allowing sick patients to see their doctor quickly while still scheduling regular visits, some doctors have individually devised some form of a carve-out model. In the carve-out model, a portion of each day's appointments are reserved for patients with short term conditions: illness, sudden rashes, or sports injuries. Under the carve-out model a doctor may instruct his scheduling secretary to leave one appointment every hour open until a week beforehand. The intent being that very sick patients will fill these spots: thus allowing them to be able to visit the doctor quickly.

If run properly, the carve-out method works beautifully. However, in practice, several problems usually arrive. First, the doctor may not have the dedication to risk a spot remaining open. The doctor will see open spots in his schedule for the following day and wish the receptionist had filled that spot with a regular checkup. The temptation to fill the carved out spot with non-urgent appointments is just too great. Another problem is that the scheduling secretary has to go through extreme efforts to keep the system running smoothly. Under traditional scheduling, when the secretary receives a call of a patient wanting an appointment, they must simply find a suitable time. Under the carve-out method however, the secretary must also decide how urgent the patient’s condition is. This sorting takes time and cannot always be done fairly. Furthermore, if patients realize that their doctor is using the carve-out model, they may exaggerate their condition on the phone to receive an earlier appointment (Murray & Berwick, 2003).

While the carve-out method works great on paper, it rarely works well in practice. However, even if it did work perfectly, it does not address the problems associated with no-show and walk-in patients. For that, another scheduling method must be devised.

C. The Advanced Access Model

The advanced access model was documented by Mark Murray, MD, MPA and Donald M. Berwick, MD, MPP in 2003 (Murray & Berwick, 2003). The advanced access model hopes to decrease the waiting time for all appointments by not allowing patients to make appointments more than a week in advance. By doing so, the scheduling secretary is relieved of the duty of evaluating patient criticality. Under this system, no appointments are made far in advance. When using traditional scheduling, a normal checkup would be made six months in advance. However, when using the advanced access model, the doctor's office would keep record of when the patient should visit again. The office would then call the patient when that time arrives. This allows for more flexibility for both the doctor and patient because the doctor can delay calling patients for checkups when a busy week arises (Murray & Berwick, 2003).

Unfortunately, this method requires just as much discipline (if not more) on the doctor's part as the carve-out method. The doctor must be able to look at the next day's schedule and not panic when it is nearly empty. The doctor will see benefits for their dedication however. All patients will receive timely care. More importantly, the office will be better able to handle an unexpected rush such as flu season by simply not calling patients due for fixed appointments. A subtle advantage is that as the time between scheduling and the appointment decreases, the no-show rate decreases as well. Because the advanced access model drastically reduces the time between scheduling and appointment, the office gets the unexpected benefit of a lower no-show rate (Vozenilek, 2009).

D. Overbooking

The most sophisticated form of scheduling is overbooking; it will be the bulk of the remainder of the research. In overbooking, the scheduler (doctor’s office) will schedule more appointments than they can handle. Overbooking does not mean double booking. Double booking schedules two patients into a single patient slot. Overbooking may however schedule an appointment every ten minutes when it can only serve a patient every fifteen minutes. The goal of overbooking is to minimize the effects of patient no-shows.

By overbooking, the family doctor aims to keep utilization high by avoiding the idle time associated with patients not showing up, but do so without greatly increasing patient wait time or employee overtime. It is important to note that patient wait time and employee overtime *will* be higher than under traditional, carve-out, and advanced access models. However, if done properly in the right situations, overbooking may greatly increase utilizations while only slightly increasing employee overtime and patient waiting time. Furthermore overbooking is the only model that directly compensates for no-show patients (LaGanga & Lawrence, 2007).

E. An Example of Overbooking

A psychiatrist's office wishes to use overbooking to protect itself from its no-show rate of 50%. It has been proven that for homogenous patient no-show rates (all patients equally likely not to show for appointment); patient meetings should be placed evenly apart throughout the day (LaGanga & Lawrence, 2007). The psychiatrist works 8 hours a day and can help a patient every hour. As such the doctor's office should create 16 spots placed evenly throughout the day: see equation 1. This places patient appointments 30 minutes apart: see equation 3.

$$Number\ of\ appointment\ slots = \frac{patient\ capacity}{1-(no\ show\ rate)} = \frac{8}{1-0.5} = 16 \quad (1)$$

$$Time\ between\ appointments = \frac{Time\ available}{Number\ of\ appointment\ slots} =$$

$$\frac{480\ minutes}{16\ slots} = 30\ minutes/slot \quad (2)$$

In this situation a variety of things can happen (2^{16} possibilities). Table II looks at a few of these possibilities. Notice that everything can work perfectly (case 5), patients may arrive bunched in the morning (case 1), patients may arrive bunched in the afternoon (case 2), too many patients may arrive (case 3), or too few patients may arrive (case 4). Table II shows each of these possibilities.

TABLE II

COMPARISON OF SPECIFIC INSTANCES IN OVERBOOKING

Time	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	Overtime	
Case 1	**Expected number of patients arrive, but bunched early**																	
Time of arrival	A1	A2	A3		A4		A5	A6	A7			A8						
Being Served	A1	A1	A2	A2	A3	A3	A4	A4	A5	A5	A6	A6	A7	A7	A8	A8		
Waiting		A2	A3	A3	A4	A4	A5	A5,6	A6,7	A6,7	A7	A7,8	A8	A8				
Case 2	**Expected number of patients arrive, but bunched late**																	
Time of arrival			A1		A2		A3		A4		A5		A6	A7		A8		
Being Served			A1	A1	A2	A2	A3	A3	A4	A4	A5	A5	A6	A6	A7	A7	A8	A8
Waiting														A7		A8		
Case 3	**Greater than expected number of patients arrive, evenly spaced**																	
Time of arrival	A1	A2	A3		A4		A5		A6		A7		A8		A9			
Being Served	A1	A1	A2	A2	A3	A3	A4	A4	A5	A5	A6	A6	A7	A7	A8	A8	A9	A9
Waiting		A2	A3	A3	A4	A4	A5	A5	A6	A6	A7	A7,8	A8	A8	A9	A9		
Case 4	**Less than expected number of patients arrive, evenly spaced**																	
Time of arrival		A1		A2		A3		A4		A5		A6		A7				
Being Served		A1	A1	A2	A2	A3	A3	A4	A4	A5	A5	A6	A6	A7	A7			
Waiting																		
Case 5	**Expected number of patients arrive, evenly spaced**																	
Time of arrival	A1		A2		A3		A4		A5		A6		A7		A8			
Being Served	A1	A1	A2	A2	A3	A3	A4	A4	A5	A5	A6	A6	A7	A7	A8	A8		
Waiting																		

Overbooking will typically allow for more patients to be seen but the office will see more patient waiting time and more overtime. The owners/managers of the company/office must consider this tradeoff before moving to an overscheduling model. However, offices with large no-show rates (like the example above) will find overbooking appealing.

V. WALK-IN PATIENTS

The walk-in patient is—in essence—the opposite of the no-show patient. While a no-show patient makes an appointment and never shows up, the walk-in patient shows up but never makes an appointment. The prevalence of no-show patients is on the rise. Patients seem to be willing to give up the benefits of continuity of care in order to be served immediately. This is evidenced by the explosive growth of walk-in clinics. In 2006, the US had around 250 immediate care clinics. In 2007, there were 800 clinics. Currently there are over 5,000 walk-in clinics (Britt, 2009). The growth in this sector has trickled over into traditional family practice; Jeffersontown Family Practice has marked considerable growth in walk-ins over the past few years and therefore hired a triage nurse. Walk-in patients are becoming increasingly common and will become a standard part of the medical community in the years to come.

VI. Simulation

The queue at a doctor's office has several levels of complexity. Foremost of which is that there are two entering populations (walk-ins and scheduled patients); but each of these populations enter the system in a different manner. Due to this complication, traditional queuing models are insufficient for satisfactory results. However, a doctor's office is highly time dependent. This makes it an ideal candidate for a simulation model. As such, it was decided to build a replica of Jeffersontown Family Practice. Once verified, this simulation can be placed under differing parameters to see how any doctor's office would react in those situations.

A. Collecting Data for Simulation

In order to be able to build a simulation model data was collected from Jeffersontown Family Practice. Most of the data collected was the doctor's and nurse's service times. Two days were selected based on those being "normal days." The workload was neither heavy nor light and the system was running normally (example: not during Christmas season). These days were November 10, 2010 and January 20,

2011. The times collected showed that for a fifteen minute appointment the doctor spent an average time with his patients of 10.45 minutes. Figure 3 uses a probability plot to show that the service times were normally distributed. In a probability plot all the data points are plotted with a non-linear vertical axis. If the data points form a straight line, then the data follows the distribution of the vertical axis.

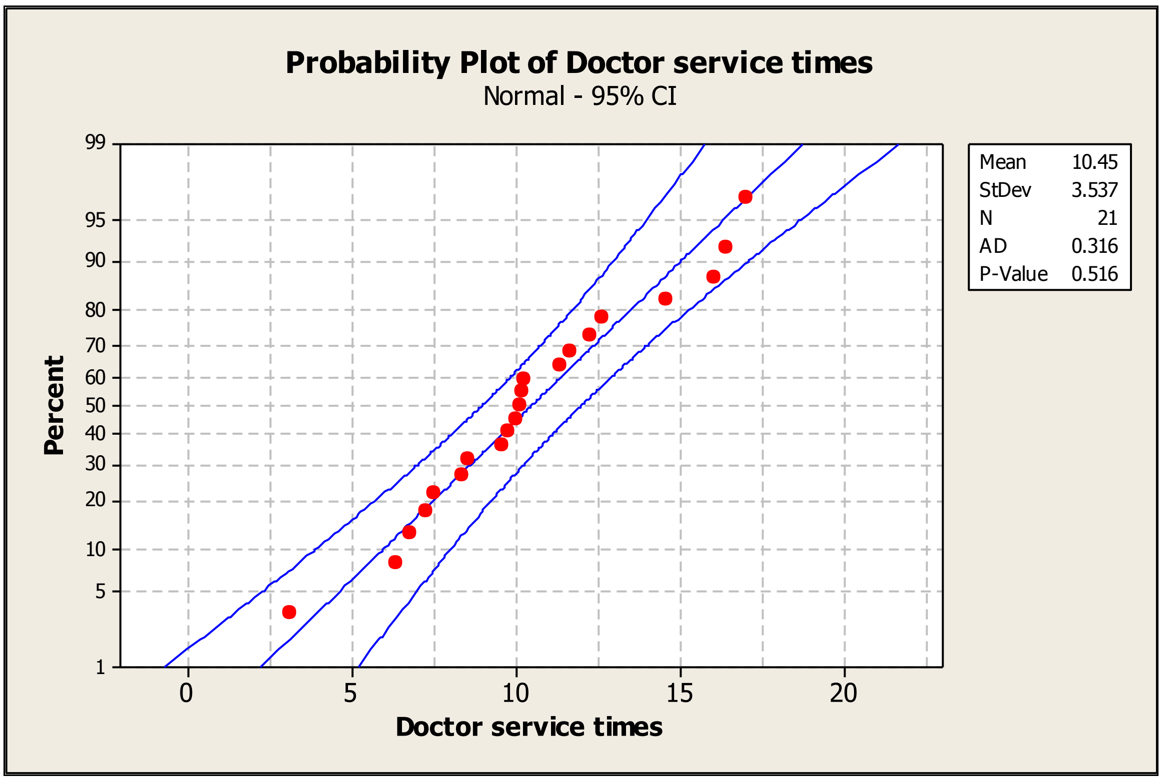


FIGURE 3 - Normal Probability Plot of the Doctor's Service Times

The final piece of data collected was the patient waiting times. These will not be used in the simulation directly, but rather used to validate the simulation during testing. Patient waiting times at Jeffersontown Family Practice were—on average—four minutes thirteen seconds.

B. Simulation Construction

With the service data collected, a simulation of Jeffersontown Family Practice was built using Arena (Arena 13). The simulation had to be flexible enough to allow for a variety of tests, but rigid enough to produce concrete results. The model was divided into three sections: a scheduled patient generator, a walk-in patient generator, and the doctor's office. After basic construction, much time was spent to make sure that the simulation gave the appropriate outputs for testing. Finally, the simulation was connected to a Process Analyzer so that multiple simulation runs could be done more quickly.

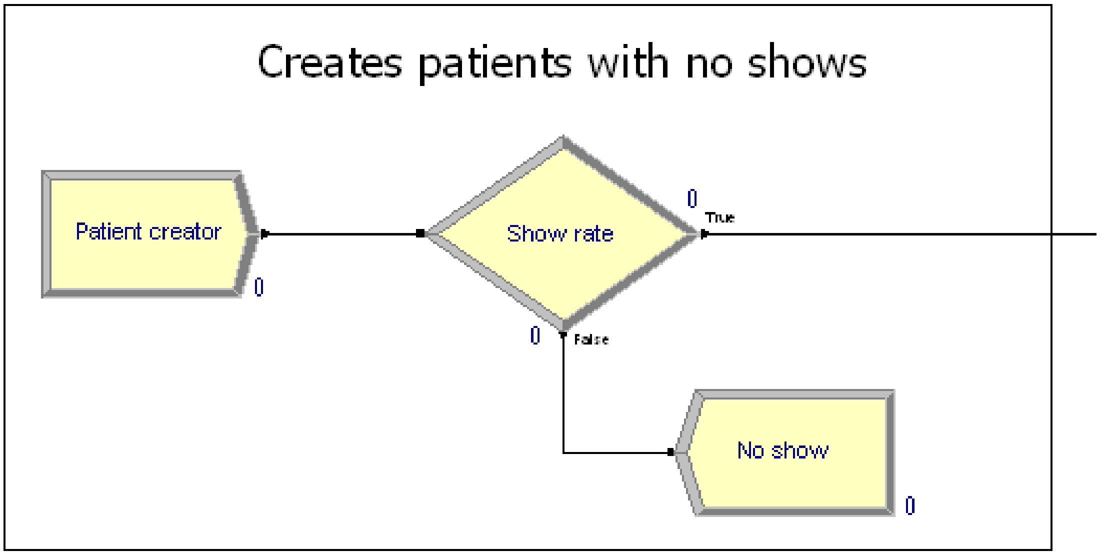


FIGURE 4 – No-Show Patient Creator

The scheduled patient generator is the simpler of the two generators. As can be seen in Figure 4, the scheduled patient generator consists of a Create Module, a Decision Module, and a Dispose Module. The Create Module (called Patient Creator in Figure 4) will create a patient at a constant rate. All patients are evenly spaced throughout the day; this is common practice in most scheduling environments and very realistic if the scheduled patients are reasonably punctual. After the patient is created, it moves to a Decision Module: called "Show Rate" in Figure 4. This module assigns the patient a random number between zero and one. It then tests to see if that randomly assigned number is less than the no-show rate. If it is, then the patient leaves through the lower portion of the diamond, otherwise, the patient exits to the right. Patients who exit to the right enter the Doctor's office. Patients exiting through the bottom are fed directly to a Dispose Module (called "No Show" in Figure 4) and removed from the simulation. This setup accurately represents the manner in which scheduled patients visit the doctor. If patients arrive in fifteen minute increments, but one doesn't show, then the time between the patient before and after the no-show patient is 30 minutes. The scheduled patient generator accurately distributes scheduled patients for the simulation.

The walk-in patient generator not only creates walk-in patients, but also gives the doctor's office the option of rejecting a walk-in patient. As can be seen in Figure 5, the walk-generator consists of one Create, one Assign, three Decision, and one Dispose Module. To start the process, the Create Module titled "Walk-in Creator" generates patients with an exponential inter-arrival time. Unfortunately, when the Create Module is set with exponential inter-arrival times, it will always initiate the day with a patient creation. This is not observed in the real Jeffersontown Family Practice. To correct this mistake, a binary variable was created titled "Destroy." The destroy variable is initially False. When the Create

Module generates its erroneous first patient, the patient is sent to the “First of day?” Decision Module. This module tests that the destroy variable is false and sends the patient downward.

The patient is then sent through an Assign Module that sets the destroy variable to true and the patient is disposed of. After this initial customer, all walk-in patients can pass through the first of day module with-out being sent to disposal. Instead they are sent to the “arrive after close?” Decision Module. This module will route all patients toward disposal that arrive after the doctor’s regular business hours to be rejected. If the patient passes this test, it is moved on to the “too busy for walk-ins” Decision Module. During the setup, the doctor’s office may specify a maximum number of patients in the office. If the walk-in patient would force the office to exceed that, then the doctor’s office rejects the walk-in patient’s business and the patient is sent to the Dispose Module. The maximum number of patient’s constraint was never used, but it was built into the simulation in case it was required. This portion of the model creates a figurative series of hurdles that the potential patient must jump before being admitted to the doctor’s office.

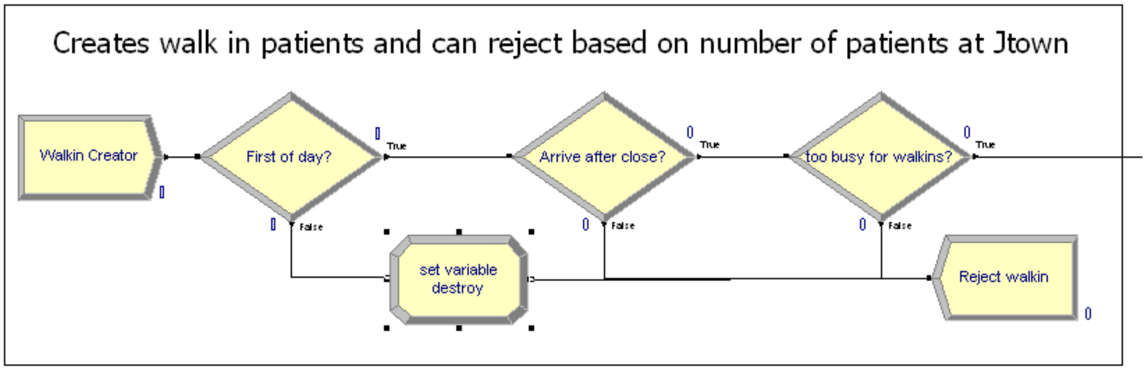


FIGURE 5 – Walk-in Patient Creator

In order to see the doctor, a walk-in patient must not be the first generated, not arrive after the doctor’s office closes, and arrive at a time that the doctor’s office is below its capacity. If all three of these conditions are met, then the patient is sent to the doctor’s office portion of the simulation.

Both of the patient generators then feed patients into the doctor’s office; this office is represented in Figure 6. The patients go through a series of modules in succession. First, the patient passes through the Assign Module “patient increase.” This increases the counter that keeps track of how many patients are at the doctor’s office by one. The patient then sees the nurse who helps the patient. Based on data collections from JFP, the service time by the nurse is a triangular distribution with a min at 20 seconds, an average at 40 seconds, and a maximum at

180 seconds. From here the patient finally visits the doctor; he will be served for a normally distributed amount of time with a mean of 10.45 minutes and a standard deviation of 3.5 minutes. The treated patient leaves the doctor module and passes through another Assign Module. This module decreases the counter telling how many patients are in the doctor's office by one. Finally, the patient goes home. This is represented by a Dispose Module in the simulation.

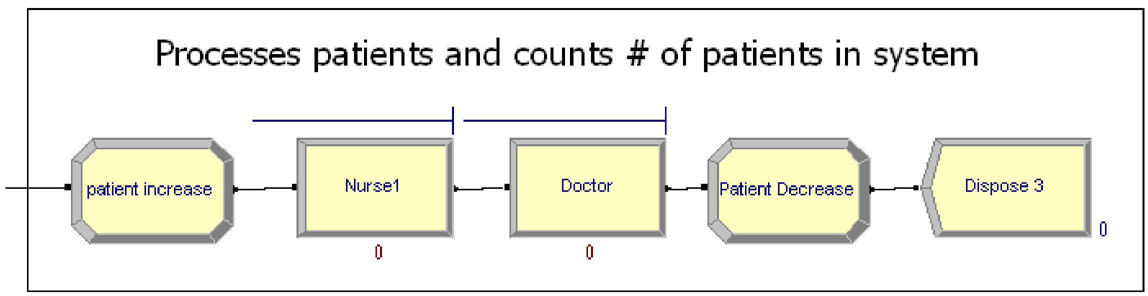


FIGURE 6 – Doctor's Office

There were three major outputs derived from the simulation. First, the average patient wait time had to be known. Fortunately, Arena automatically collects this piece of data. Second, the doctor's idle time needed to be known. And finally, the doctor's expected amount of overtime needed to be known. The last two were not as simple to obtain from the model. While Arena does keep track of the doctor's utilization—and correspondingly idle time—it collected the utilization of the entire run. In this run, the simulation will run for six hours, but the doctor’s office is only open for four hours. If left untouched, the doctor’s utilization would appear to be lower than reality. To fix this, two statistics were created. One measured the doctor’s utilization during the first four hours of the day while the other tracked the doctor’s utilization during the final two hours. These statistics were transformed into doctor idle time and doctor overtime.

In order to be able to easily control the simulation, Arena’s Process Analyzer was used. This allows the user to effortlessly run the simulation many times while not being near the computer. The process analyzer was set up to allow the user to change four model parameters. These are the number of scheduled patients, the walk-in patient rate, the no-show rate, and the level at which the doctor’s office rejects walk-in patients. Ultimately, these four categories are sufficient for all subsequent testing. The Process Analyzer was set up to gather the three responses described earlier: patient response, doctor utilization, and doctor overtime. With the simulation in place, all that was left before testing could begin was a simple verification. (Arena 13)

C. Verification

In order to be able to trust the results of the simulation, the simulation was verified. Verification is the process of checking a simulation to see if it produces the same outputs as the actual system being simulated. This was done by setting the simulation's input parameters to those observed at JFP and seeing how close the simulation's sample mean patient wait time was to JFP's average patient wait time. The first attempt at this failed. The average patient waiting time at JFP was four minutes thirteen seconds; but the simulation predicted that the waiting time should have been twelve seconds. Clearly there was some discrepancy between the model and reality.

The most obvious difference is that in real life patients do not always arrive exactly on time. There is a certain level of earliness or tardiness. The simulation however was deliberately built to not include this uncontrollable source of variation. For the sake of verification, a series of modules was created that would stagger the scheduled patients to the level of tardiness observed at JFP. The times taken at JFP showed that patients arrived in a normally distributed manner with a standard deviation of seven minutes and were four minutes early on average.

With the tardiness correction in place, the simulation was run again. This time, the average patient waiting time had risen to three minutes and eleven seconds. This is still one minute and one second less than the observed average patient waiting time. However, it is an acceptable gap. The remaining minute can easily be allotted to unseen but minor variations at JFP that were not captured in the model. More likely however, most of this discrepancy is due the limited number of samples in the observed average patient wait time. Thus the simulation was deemed acceptable for further research.

VII. SCHEDULED VS. WALK-IN PATIENTS

In the simulation described above, two basic types of patients are seen by the doctor: scheduled and walk-in patients. A scheduled patient is a person who makes an appointment before entering the doctor's office. By contrast, the walk-in patient will go to the doctor without an appointment. There are several similarities and differences between these two patient types. They are similar in that each requires the same amount of time with the doctor and nurse. Also, neither patient is given preferential treatment in the doctor queue. Patients are seen in the order that they physically arrive at the doctor's office. The primary difference between the two is the arrival pattern in which the patient enters the system. The scheduled patients arrive at a near constant rate throughout the day. By contrast, the walk-in patients' inter-arrival time follows an exponential distribution. The scheduled patient may be late or early, but because their variations are derived from a schedule it is much less likely that several scheduled patients will arrive in quick succession. The number of scheduled patients for the day is also known beforehand (assuming 0% no show).

With this arrival disparity, it seems logical that scheduled patients would be preferred by the system. After all, scheduled patients have less variation in their manner of arrival and a decrease in variation should help both the utilization of the doctor and the average patient waiting time in the doctor's office.

To test this theory, the simulation was run to decrease a variable titled "waiting score". The waiting score is weighted sum of the total patient wait time, waiting time of the doctor per day, and the total overtime seen by the office. The weights placed in front of each variable allow each doctor's office to define their own tradeoffs between patient wait time and doctor idle time. For the remainder of the study, the doctor's time will be worth twice as much as the patients waiting time. Also, the doctor's overtime will be worth twice as much as his/her regular time. These values are used to form equation 3. As the waiting score decreases the entire waiting time of the system decreases (a very desirable situation).

$$Waiting\ Score = 0.5 * \overline{Patient\ Wait\ Time} + \overline{Dr.Wait\ Time} + 2 * Dr.OverTime \quad (3)$$

To compare scheduled and walk-in patients the no show rate in the simulation was set to a constant 20%. Four sets of runs were conducted with the expected number of walk-ins at 0, 4, 8, and 12 per morning, respectively. Table III shows an example of one of these sets of runs. Each run/scenario was run 250 times; this gave the waiting score a confidence interval of less than +/- 0.1. Each set will be run at all possible levels of scheduled patients. Each level of walk-ins will have an optimal level of scheduled patients where the total amount of time spent waiting by both doctors and patients is at a minimum. By comparing the best case of each level of walk-ins, we can begin see the effects of having more or fewer walk-in patients. Please note, a doctor may value his own time much more than a patient's. In this case the same general trends occur, but at a different optimal number of scheduled patients.

TABLE III

Set of Runs with 12 Expected Walk-ins (Best Run Highlighted)

	Input			Daily			
Name	**Daily Scheduled Patients**	**Ave. Num. of Walk-ins**	**Chance of Showing (%)**	**Patient Waiting (min/ day)**	**Dr. idle time (min/ day**	**OT**	**Waiting Score**
Scenario 01	0	12	80	59	118	7	**162**
Scenario 02	2	12	80	83	105	8	**161**
Scenario 03	4	12	80	103	89	7	**155**
Scenario 04	6	12	80	147	73	10	**167**
Scenario 05	8	12	80	196	59	15	**187**
Scenario 06	10	12	80	250	47	18	**207**
Scenario 07	12	12	80	321	40	21	**242**
Scenario 08	14	12	80	452	29	28	**312**
Scenario 09	16	12	80	537	23	34	**359**
Scenario 10	18	12	80	734	16	42	**467**
Scenario 11	20	12	80	863	13	46	**537**
Scenario 12	22	12	80	1094	10	52	**661**
Scenario 13	24	12	80	1298	7	56	**770**
Scenario 14	26	12	80	1508	7	57	**875**
Scenario 15	28	12	80	1744	6	59	**996**
Scenario 16	30	12	80	1923	5	60	**1085**

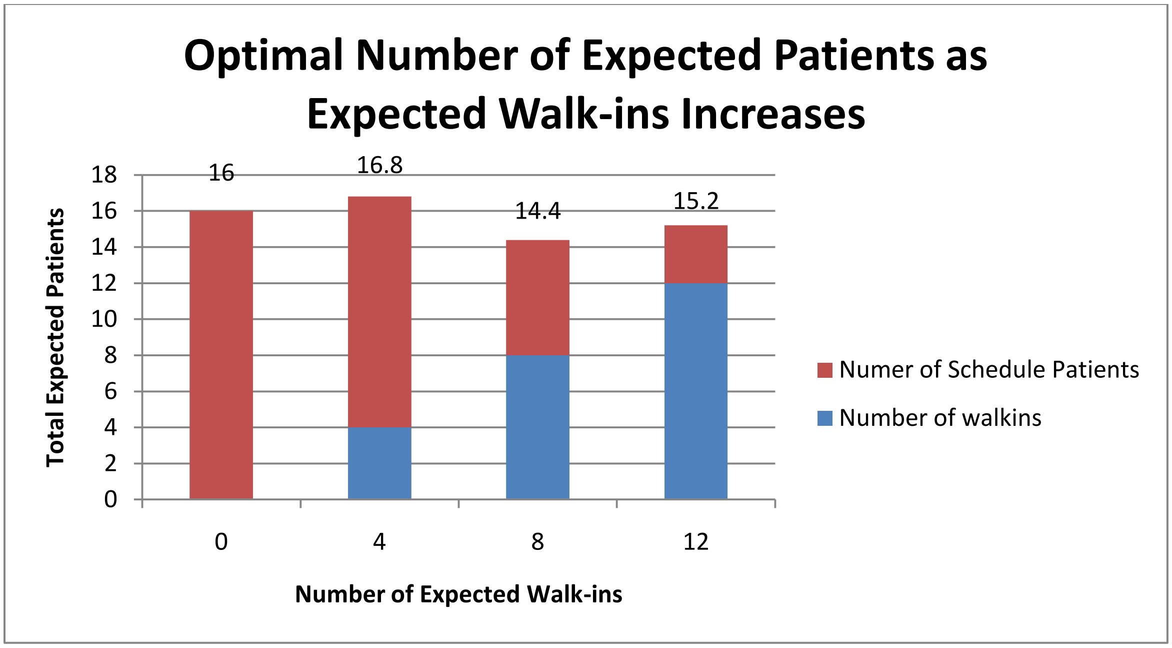


FIGURE 7 - Maximum Expected Patients as Expected Walk-ins Increases

Next, the study addressed the question of whether or not the number of walk-in patients affected the average number of patients seen by the doctor. To check this, all levels of walk-ins were set to their best level of scheduled patients. Figure 7 shows that the total patients expected each day remains the same as the number of walk-in patients rises. The total number of patients the doctor can expect to see stays at about 15.5 patients per morning. This shows that a doctor's optimal patient load is not dependent on the type of patient being seen. Scheduled and walk-in patients can be swapped in an approximate 1:1 ratio without affecting the total patient load.

Next, the study evaluated what happens to the total waiting time as more walk-in patients enter the system. Simply put, as a larger portion of the patient population become walk-in patients, the total daily waiting time per patient rises. Figure 8 shows the expected waiting time for all patients as the number of walk-in patients in the system increases. This rise occurs despite the fact that the doctor is unable to see more patients. The added waiting time is not due to an increase in doctor utilization, but due purely to increased variation in patient arrival.

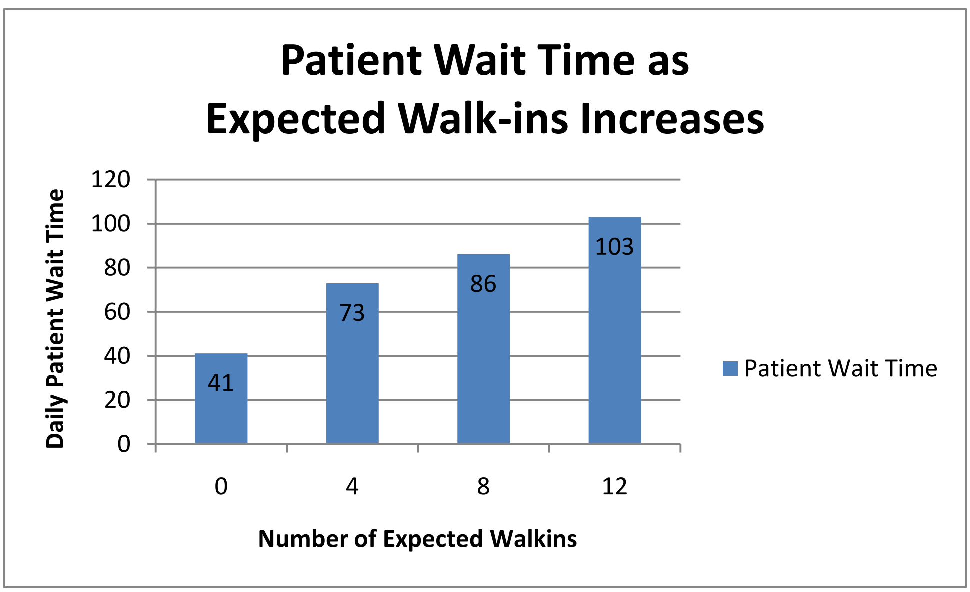


FIGURE 8 - Expected Walk-ins and Patient Wait Time

It is possible that the overall system may see improvement at the patients' expense. As patient waiting time increases, the Doctor's idle time may decrease even faster. This is why a grocery store may decrease the number of checkout lines. While the customer is forced to wait longer, the remaining cashiers wait very little for customers. Unfortunately, this is not the case for the system studied here. As can be seen in Figure 9 and 10, both the doctor's idle time and overtime increase along with the patient waiting time. It can be easily seen (Figure 11) that everyone is forced to spend more time waiting as the number of walk-in patients rises. Please note that nothing else has changed in the simulation; therefore, the added wait is purely due to the added variation of walk-in patients as compared to scheduled patients.

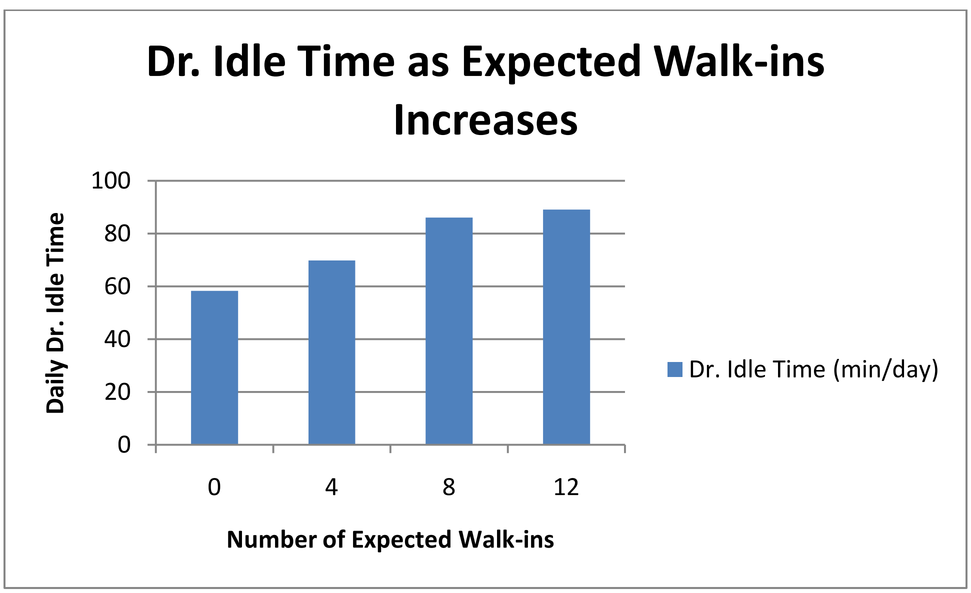


FIGURE 9 – Expected Walk-ins and Doctor Idle Time

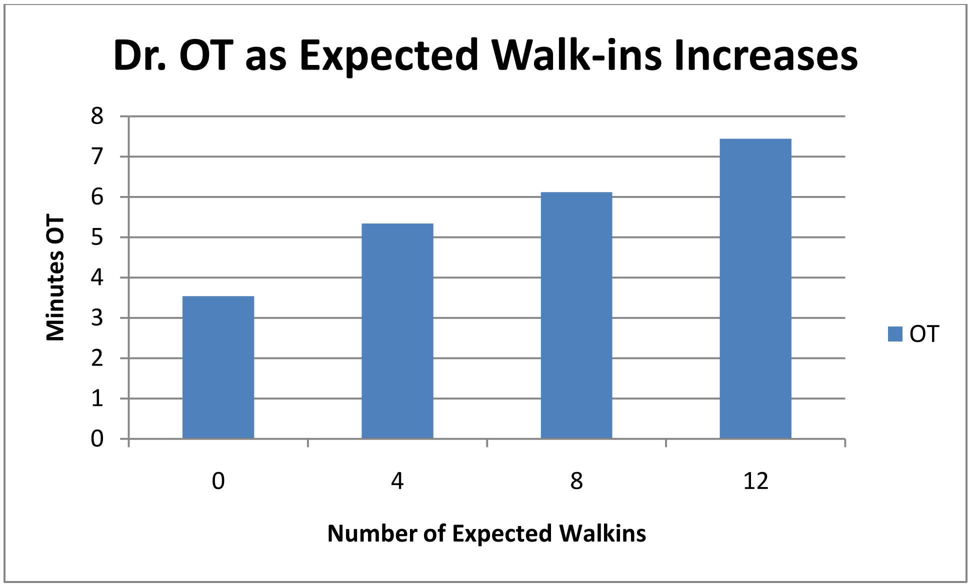


FIGURE 10 – Expected Walk-ins and Office OT

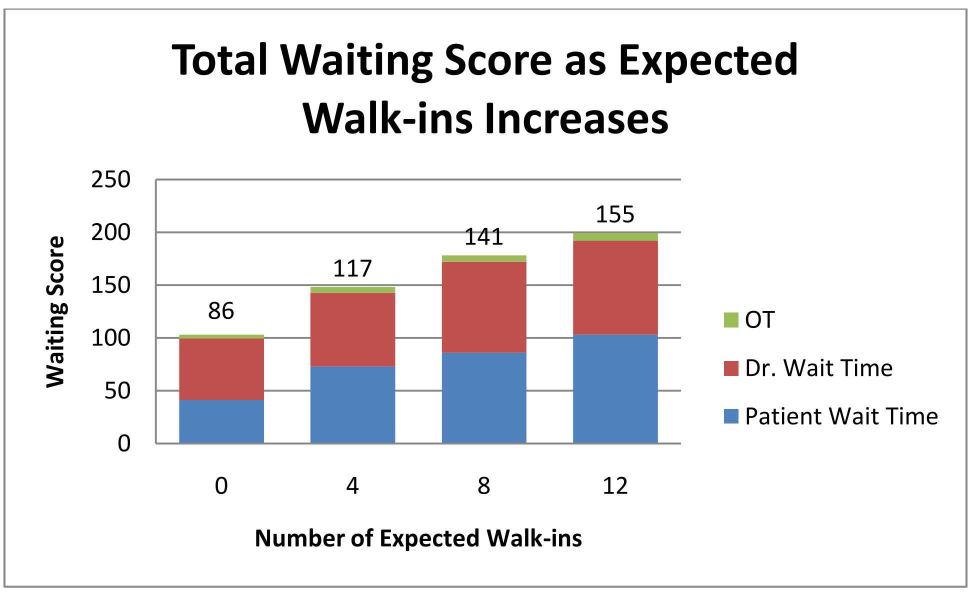


FIGURE 11 – Expected Walk-ins and Waiting Score

VIII. EFFECT OF SHOW RATE ON WAITING TIME

The effect of the no-show rate on the waiting score of the system was evaluated next. More specifically, the study would research if a system with a high no-show rate can run as efficiently was a system with a low no-show rate if their scheduled patient levels were each set optimally. To evaluate this, a series of simulations were run at varying levels of walk-in rates and no-show rates. The results show that even optimal scheduling cannot completely eliminate the wait caused by a high no-show rate.

In order to conduct a proper experiment, the simulation was run at a variety of fields. The expected number of walk-ins was set at 0, 5.7, 11.4, and 17.1 walk-ins per day. The no-show rate was set at five levels: 40%, 30%, 20%, 10% and 0%. This range encompasses all no-show levels found during the literary research. All possible combinations of walk-ins and no-show rates were considered (20 combinations). Each combination was run at multiple levels of scheduled patients. All individual scenarios were run 250 times to give the waiting score a confidence interval of less than +/- 0.1. It was assumed that a doctor's office will be running near the ideal number of scheduled patients. To make this assumption valid, for each combination of walk-ins and no-show rate, the model chose the scheduled patient's level with the lowest waiting score. The same formula for "total waiting time" was used here as in the previous section. Other coefficients could be chosen without effecting overall findings. Different coefficients in the waiting score formula would merely change the chosen number of scheduled patients.

The model is allowed to choose the scheduled patient level with the lowest waiting score. This corresponds to the best level of scheduled patients. Figure 12 charts the best total score for each of the twenty combinations of no-show rate and walk-in rate. As such, each point shows the waiting score of the optimal scheduled patient score for that particular combination of no-show and walk-in rate. Two major trends can be identified. First, as the number of walk-ins increases, the waiting scores increase. This is observed by each line being higher than the previous line; the 5.7 walk-in rate line is slightly higher than the 0 walk-in rate line for example. This reinforces the conclusion that even when optimized, walk-ins cause more waiting than do scheduled patients. Even when the doctor is at an optimal scheduled patient level for his/her walk-in rate, 13 shows that there is more waiting time as the proportion of walk-ins to scheduled patients increases.

Second, as patients become more likely to show up for appointments, the waiting score decreases. This can be observed in Figure 12 in the negative slope of each of the lines. Even if the doctor adjusts the number of patients scheduled, he cannot completely compensate for the variation caused by some patients respecting their appointments and others not. With this in mind, a doctor should attempt to increase his patient's show rate. By increasing the office's show rate, the overall waiting time for doctor and patient would decrease and allow the doctor to spend more time doing what he does best: help patients.

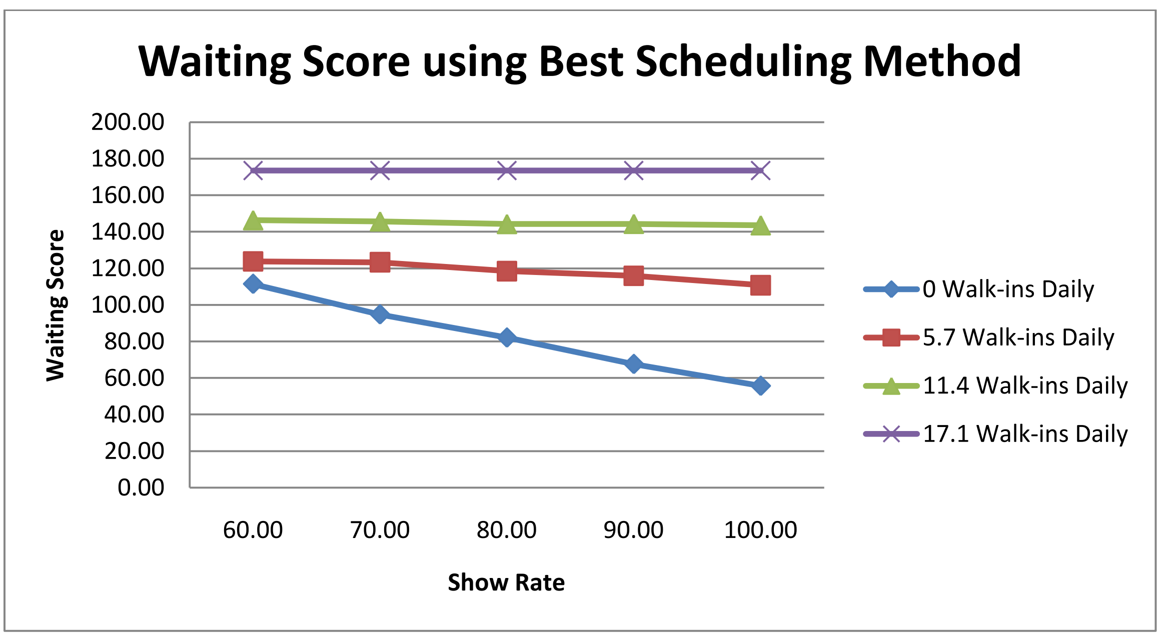


FIGURE 12 - Best Waiting Score for Selected Levels of Show Rate and Walk-in Rate

IX. RESULTS

Research has shown that there are many scheduling methods for appointment based systems, but overbooking is the most common method that directly accounts for no-shows. With this in mind, several details of the inner workings of overbooking need to be analyzed. When this is done, several overarching conclusions can be drawn.

First, scheduled patients are better than walk-in patients. By better, it is meant that scheduled patients are able to be seen while generating less idle time for the doctor and for other patients. This is due to the more consistent pattern in which scheduled patients enter the system. A doctor may switch out scheduled patients for walk-in patients in a 1:1 ratio without affecting his expected number of patients per day (Figure 7). However, as a larger portion of a doctor's patient base became walk-in patients, patients are forced to wait longer and the doctor's utilization decreases: as seen in Figure 11 from earlier.

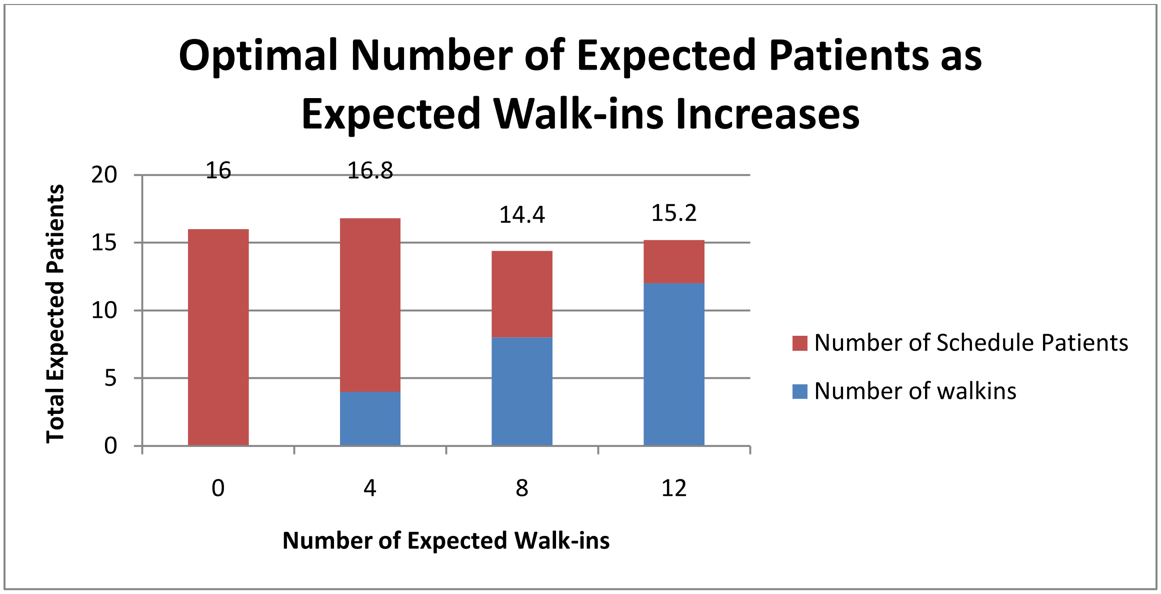


FIGURE 7 - Maximum Expected Patients as Expected Walk-ins Increases

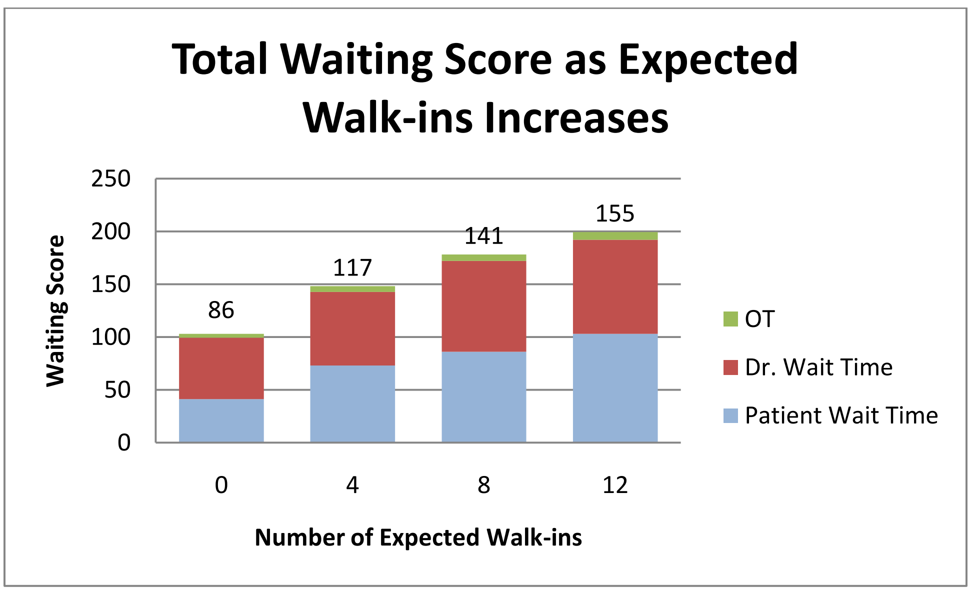


FIGURE 11 – Expected Walk-ins and Waiting Score

Second, as the no-show rate decreases, the waiting score increases. Overbooking minimizes the burden placed on the system by no show patients. However, in offices with overbooking, the office with a lower no-show rate will always have less total waiting time than an office with a higher no-show rate (as seen in Figure 12). The benefit of a low no-show rate is more dramatic for doctor's offices with more scheduled patients than walk-in patients. The variation caused by no-shows cannot be completely compensated for by overbooking alone.

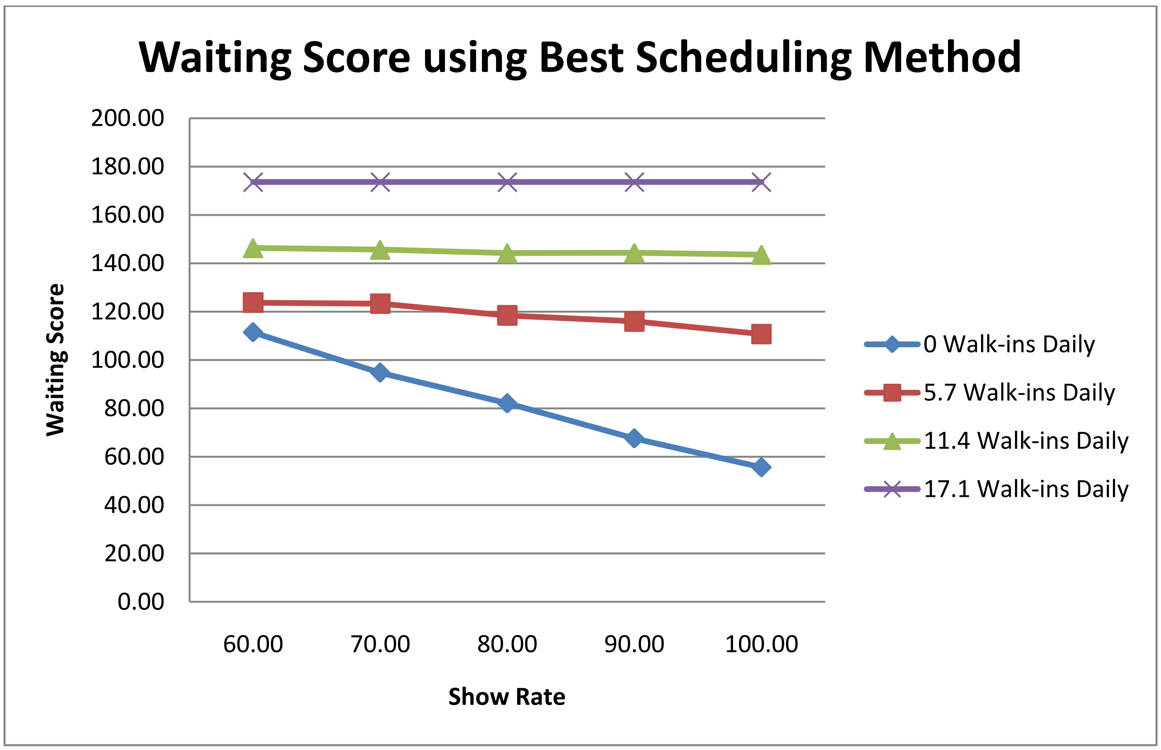


FIGURE 12 - Best Waiting Score for Selected Levels of Show Rate and Walk-in Rate

X. CONCLUSIONS

In order to reduce the cost of healthcare, waste must be eliminated from the healthcare industry. One low hanging fruit is to eliminate doctor and patient waiting time by compensating for no-show patients. To do this, several elaborate scheduling methods have been devised from practicing doctor’s offices and the academic realm. One such method is overbooking. In overbooking, patients are scheduled closer together than the doctor is able to accommodate them. This is compensated for by patients not showing up for appointments. If done well, overbooking can greatly increase doctor utilization, while only marginally increasing patient wait time.

Sometimes walk-in patients are allowed to enter a doctor’s office using an overbooking scheduling system. To accommodate this, a simulation was built based on Jeffersontown Family Practice. It was discovered that—in overbooking scheduling systems—the expected number of patients was not affected by the mix of scheduled and walk-in patients. However, it was also discovered that as the number of walk-in patients increased, so did the expected patient waiting time, the expected doctor idle time, and the expected doctor overtime. Thus, it is recommended that doctors attempt to minimize their number of walk-in patients, especially if they can convert walk-in patient into scheduled patients. Critical care centers may allow a patient to be seen without the effort of making an appointment, but such system will see more patient waiting time and more doctor idle time. With this in mind, critical care centers should not replace the common family practice.

It may be reasonable to divide a doctor's office's day into two segments. The first segment would operate under scheduled appointments and help non-urgent cases. The second segment of the day would only help walk-in patients. This would keep waiting times lower for the patients courteous enough to schedule appointment, but allow sick patients to see their doctor the same day they become ill. This method would also be superior to having two facilities—one family practice and one critical care center—because having a single facility would maintain continuity of care. The primary hurdle would be for a doctor to train his/her patient base on whether they should enter the system during the first for second part of the day.

It was also discovered that while overbooking lessens the waiting and idle time caused by no-show patients, it did not completely eliminate the problem. With this in mind, a doctor’s office should always attempt to decrease their patient base’s no-show rate when possible. This may mean scheduling closer to the appointment, calling patients the day before their appointment, or charging penalties for not showing up for a scheduled appointment. An office without no-shows is superior to an office with no-shows but overbooks to compensate.

It is important to note that while the majority of this study’s findings have been focused around the healthcare industry and family practice doctor’s offices, the findings contained herein can be applied to all systems where people schedule appointments. These can include tattoo parlors, dentist offices, restaurants that seat primarily reservations, etc.

It is the sincere hope of the author that the healthcare industry will begin using more sophisticated methods of scheduling. It is a truly simple way to allow more people to see a doctor while also decreasing the cost of the visit.

XI. RECOMMENDATIONS

Extensive efforts were given to attempting to create a formula that would connect the relationship between service time, time between scheduled patients, time between walk-in patients, the no-show rate, and a constant connecting the relative value between the patient’s time and the doctor’s time. This formula would then be derived. In the final form, the formula should allow any doctor’s office to know how far apart to set scheduled patients in order to minimize the total wait time. Thus if a doctor’s office knew it’s no-show rate, walk-in rate, and doctor’s service rate, then they could easily set up a near optimum overbooking system. In order to accomplish this, many simulations were run and placed into a DOE with the goal of finding a regression. Unfortunately, while the regression was good, it was unable to provide results in the amount of detail required for all cases. Future research could attempt to create this equation more precisely.

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APPENDIX I

Data from Jeffersontown Family Practice

Doctor Service Times

0:03:05
0:10:00
0:07:15
0:11:40
0:06:20
0:14:35
0:17:00
0:09:35
0:10:10
0:07:30
0:09:45
0:10:15
0:10:05
0:11:20
0:16:00
0:08:20
0:16:25
0:06:45
0:12:35
0:12:15
0:08:30

Patient Waiting Times

0.00000
9.60000
5.46326
2.31600
6.50000
2.50000
5.62996
0.00000
3.87996
6.20000
7.96326
6.96326
5.71326
2.10000
0.00000
0.00000

Nurse Service Times
0:01:10
0:01:55
0:01:50
0:03:15
0:03:35
0:02:15
0:02:45
0:01:45
0:02:30
0:02:45
0:05:55
0:02:55
0:07:15
0:02:55
0:02:00

APPENDIX II

ARENA Output used When Comparing Scheduled and Walk-in Patients (Section VII)

		Input				Output			Daily			
Name	Reps	Daily Scheduled Patients	Walk-in Rejection Level	Ave. Num. of Walk-ins	Chance of Showing	Dr. Queue Waiting time	Regular Time Utilization	OT Utilization	Patient Waiting	Dr. Waiting	OT	Total
Scenario 01	250	0	9999	0	80	0.0	0.0	0.0	0.0	240.0	0.0	240.0
Scenario 02	250	2	9999	0	80	0.0	0.1	0.0	0.0	223.4	0.0	223.4
Scenario 03	250	4	9999	0	80	0.0	0.1	0.0	0.0	206.6	0.0	206.6
Scenario 04	250	6	9999	0	80	0.0	0.2	0.0	0.0	190.1	0.0	190.1
Scenario 05	250	8	9999	0	80	0.0	0.3	0.0	0.0	172.6	0.0	172.6
Scenario 06	250	10	9999	0	80	0.0	0.4	0.0	0.0	155.8	0.0	155.8
Scenario 07	250	12	9999	0	80	0.0	0.4	0.0	0.0	139.7	0.0	139.7
Scenario 08	250	14	9999	0	80	0.0	0.5	0.0	0.4	122.6	0.2	123.2
Scenario 09	250	16	9999	0	80	0.2	0.6	0.0	2.3	106.3	0.3	108.1
Scenario 10	250	18	9999	0	80	0.5	0.6	0.0	7.4	89.5	1.0	95.3
Scenario 11	250	20	9999	0	80	1.1	0.7	0.0	18.1	73.7	1.6	85.8
Scenario 12	250	22	9999	0	80	2.3	0.8	0.1	41.1	58.3	3.5	86.0
Scenario 13	250	24	9999	0	80	4.0	0.8	0.1	76.0	45.6	6.6	96.8
Scenario 14	250	26	9999	0	80	6.5	0.9	0.2	135.3	32.6	10.7	121.7
Scenario 15	250	28	9999	0	80	9.9	0.9	0.3	222.4	23.5	17.3	169.4
Scenario 16	250	30	9999	0	80	14.0	0.9	0.4	337.2	17.0	26.4	238.4

		Input				Output			Daily			
Name	**Reps**	**Daily Scheduled Patients**	**Walk-in Rejection Level**	**Ave. Num. of Walk-ins**	**Chance of Showing**	**Dr. Queue Waiting time**	**Regular Time Utilization**	**OT Utilization**	**Patient Waiting**	**Dr. Waiting**	**OT**	**Total**
Scenario 01	250	0	9999	4	80	0.8	0.2	0.0	3.3	197.3	1.9	202.6
Scenario 02	250	2	9999	4	80	1.3	0.2	0.0	7.4	180.7	1.7	187.9
Scenario 03	250	4	9999	4	80	1.8	0.3	0.0	12.6	163.2	1.6	172.8
Scenario 04	250	6	9999	4	80	1.8	0.4	0.0	16.2	148.1	1.7	159.7
Scenario 05	250	8	9999	4	80	2.1	0.5	0.0	21.7	131.8	1.7	146.1
Scenario 06	250	10	9999	4	80	2.2	0.5	0.0	26.8	115.2	2.3	133.3
Scenario 07	250	12	9999	4	80	2.6	0.6	0.0	35.0	98.4	2.4	120.7
Scenario 08	250	14	9999	4	80	3.4	0.7	0.1	51.9	83.8	4.5	118.7
Scenario 09	250	16	9999	4	80	4.3	0.7	0.1	72.9	69.8	5.3	117.0
Scenario 10	250	18	9999	4	80	5.4	0.8	0.1	99.7	56.6	8.0	122.4
Scenario 11	250	20	9999	4	80	7.6	0.8	0.2	153.0	41.3	11.5	140.7
Scenario 12	250	22	9999	4	80	10.5	0.9	0.3	226.2	30.7	16.9	177.6
Scenario 13	250	24	9999	4	80	14.6	0.9	0.4	339.5	22.8	25.1	242.7
Scenario 14	250	26	9999	4	80	19.0	0.9	0.6	471.9	16.3	33.4	319.1
Scenario 15	250	28	9999	4	80	24.3	0.9	0.7	642.5	12.2	41.0	415.6
Scenario 16	250	30	9999	4	80	29.9	1.0	0.8	836.6	9.4	49.7	527.1

		Input				Output			Daily			
Name	Reps	Daily Scheduled Patients	Walk-in Rejection Level	Ave. Num. of Walk-ins	Chance of Showing	Dr. Queue Waiting time	Regular Time Utilization	OT Utilization	Patient Waiting	Dr. Waiting	OT	Total
Scenario 01	250	0	9999	8	80	2.5	0.3	0.1	19.9	158.9	4.0	176.8
Scenario 02	250	2	9999	8	80	3.1	0.4	0.1	29.3	142.8	3.5	164.4
Scenario 03	250	4	9999	8	80	3.5	0.5	0.1	39.5	126.0	3.4	152.5
Scenario 04	250	6	9999	8	80	4.2	0.5	0.1	54.0	109.7	5.4	147.5
Scenario 05	250	8	9999	8	80	5.2	0.6	0.1	74.4	93.4	5.0	140.5
Scenario 06	250	10	9999	8	80	6.1	0.7	0.1	97.8	78.7	7.3	142.1
Scenario 07	250	12	9999	8	80	7.6	0.7	0.1	133.9	65.5	8.9	150.2
Scenario 08	250	14	9999	8	80	9.8	0.8	0.2	187.7	49.9	13.8	171.4
Scenario 09	250	16	9999	8	80	11.1	0.8	0.3	231.8	42.2	15.6	189.3
Scenario 10	250	18	9999	8	80	15.7	0.9	0.4	351.4	30.7	25.5	257.4
Scenario 11	250	20	9999	8	80	20.1	0.9	0.5	482.0	21.1	32.3	326.7
Scenario 12	250	22	9999	8	80	22.7	0.9	0.6	580.1	16.3	37.8	382.0
Scenario 13	250	24	9999	8	80	28.5	0.9	0.8	774.6	12.2	45.1	489.8
Scenario 14	250	26	9999	8	80	34.3	1.0	0.8	988.4	9.1	49.9	603.0
Scenario 15	250	28	9999	8	80	38.5	1.0	0.9	1171.4	7.7	55.3	703.9
Scenario 16	250	30	9999	8	80	42.4	1.0	1.0	1355.4	6.7	57.1	798.5

		Input				Output			Daily			
Name	Reps	Daily Scheduled Patients	Walk-in Rejection Level	Ave. Num. of Walk-ins	Chance of Showing (%)	Dr. Queue Waiting time	Regular Time Utilization	OT Utilization	Patient Waiting	Dr. Waiting	OT	Total
Scenario 01	250	0	9999	12	80	5.0	0.5	0.1	59.5	117.6	7.4	**162.1**
Scenario 02	250	2	9999	12	80	6.1	0.6	0.1	82.9	104.6	7.6	**161.3**
Scenario 03	250	4	9999	12	80	6.8	0.6	0.1	102.9	89.0	7.4	**155.4**
Scenario 04	250	6	9999	12	80	8.7	0.7	0.2	147.0	73.2	10.2	**167.1**
Scenario 05	250	8	9999	12	80	10.7	0.8	0.2	196.5	58.8	14.8	**186.6**
Scenario 06	250	10	9999	12	80	12.5	0.8	0.3	250.0	47.3	17.6	**207.5**
Scenario 07	250	12	9999	12	80	14.8	0.8	0.4	320.6	39.6	21.2	**242.4**
Scenario 08	250	14	9999	12	80	19.5	0.9	0.5	452.1	29.3	28.4	**312.1**
Scenario 09	250	16	9999	12	80	21.6	0.9	0.6	536.5	22.8	33.9	**358.9**
Scenario 10	250	18	9999	12	80	27.8	0.9	0.7	734.4	15.6	42.2	**467.3**
Scenario 11	250	20	9999	12	80	30.8	0.9	0.8	862.7	13.0	46.2	**536.7**
Scenario 12	250	22	9999	12	80	37.0	1.0	0.9	1093.9	9.6	52.1	**660.7**
Scenario 13	250	24	9999	12	80	41.6	1.0	0.9	1298.4	7.4	56.5	**769.5**
Scenario 14	250	26	9999	12	80	46.0	1.0	1.0	1508.3	6.7	57.1	**875.1**
Scenario 15	250	28	9999	12	80	50.7	1.0	1.0	1743.9	5.5	59.5	**996.4**
Scenario 16	250	30	9999	12	80	53.4	1.0	1.0	1922.8	5.0	59.5	**1085.5**

APPENDIX III

Arena Output used to evaluate the Effect of the No-Show Rate on the Waiting Score (Section VIII)

		Input				Output			Daily			
Scenario	reps	Daily Scheduled Patients	Walk-in Rejection Level	Ave. Num. of Walk-ins	Chance of Showing	Ave Patient Waiting time	Dr Regular Time Utilization	Dr. OT Utilization	**Patient Waiting**	**Dr. Waiting**	**OT**	**Total**
1	250	0.0	9999	0.0	60	0.0	0.0	0.0	0.0	240.0	0.0	240.0
2	250	3.3	9999	0.0	60	0.0	0.1	0.0	0.0	220.8	0.0	220.8
3	250	6.7	9999	0.0	60	0.0	0.2	0.0	0.0	202.6	0.0	202.6
4	250	10.0	9999	0.0	60	0.0	0.3	0.0	0.0	177.8	0.0	177.8
5	250	13.0	9999	0.0	60	0.0	0.3	0.0	0.1	157.9	0.0	158.0
6	250	15.9	9999	0.0	60	0.1	0.4	0.0	1.1	145.7	0.0	146.2
7	250	16.2	9999	0.0	60	0.1	0.4	0.0	1.3	139.9	0.0	140.6
8	250	20.5	9999	0.0	60	0.8	0.5	0.0	9.3	114.2	0.1	119.0
9	250	22.8	9999	0.0	60	1.4	0.6	0.0	18.6	102.0	0.1	111.4
10	250	0.0	9999	5.7	60	1.5	0.2	0.0	8.7	181.9	0.1	186.4
11	250	3.3	9999	5.7	60	2.2	0.3	0.0	16.7	161.5	0.1	170.0
12	250	6.7	9999	5.7	60	2.6	0.4	0.0	24.8	143.8	0.1	156.3
13	250	10.0	9999	5.7	60	3.4	0.5	0.0	40.0	117.4	0.2	137.7
14	250	13.0	9999	5.7	60	4.2	0.6	0.0	57.1	100.1	0.5	129.6
15	250	15.9	9999	5.7	60	4.7	0.6	0.0	71.9	91.0	0.2	127.4
16	250	16.2	9999	5.7	60	4.5	0.6	0.0	69.9	87.6	0.6	123.7
17	250	20.5	9999	5.7	60	7.4	0.7	0.0	133.9	63.1	1.3	132.6
18	250	22.8	9999	5.7	60	10.4	0.8	0.0	202.0	50.6	2.1	155.8
19	250	0.0	9999	11.4	60	4.4	0.5	0.0	50.4	125.5	0.4	151.4
20	250	3.3	9999	11.4	60	5.8	0.6	0.0	77.6	106.8	0.4	146.3
21	250	6.7	9999	11.4	60	7.3	0.6	0.0	113.1	91.2	0.7	149.1
22	250	10.0	9999	11.4	60	9.6	0.7	0.0	166.7	70.6	1.7	157.3
23	250	13.0	9999	11.4	60	12.3	0.8	0.1	236.5	54.0	3.1	178.5
24	250	15.9	9999	11.4	60	14.4	0.8	0.1	302.2	47.0	3.2	204.6

25	250	16.2	9999	11.4	60	15.4	0.8	0.1	325.2	44.9	4.6	216.6
26	250	20.5	9999	11.4	60	22.1	0.9	0.1	523.2	27.4	7.6	304.2
27	250	22.8	9999	11.4	60	25.3	0.9	0.2	634.0	24.5	9.0	359.5
28	250	0.0	9999	17.1	60	10.8	0.7	0.0	184.9	76.6	2.3	173.5
29	250	3.3	9999	17.1	60	14.3	0.7	0.1	272.7	61.4	3.1	203.9
30	250	6.7	9999	17.1	60	15.7	0.8	0.1	332.1	50.6	3.5	223.8
31	250	10.0	9999	17.1	60	20.1	0.8	0.1	465.1	38.4	6.7	284.3
32	250	13.0	9999	17.1	60	26.5	0.9	0.2	659.4	28.3	9.5	377.1
33	250	15.9	9999	17.1	60	31.8	0.9	0.2	848.3	19.9	11.0	466.0
34	250	20.5	9999	17.1	60	42.4	0.9	0.3	1245.5	13.7	17.5	671.5
35	250	20.5	9999	17.1	60	42.4	0.9	0.3	1245.5	13.7	17.5	671.5
36	250	22.8	9999	17.1	60	48.4	1.0	0.3	1488.2	12.0	20.6	797.4
37	250	0.0	9999	0.0	70	0.0	0.0	0.0	0.0	240.0	0.0	240.0
38	250	3.3	9999	0.0	70	0.0	0.1	0.0	0.0	217.9	0.0	217.9
39	250	6.7	9999	0.0	70	0.0	0.2	0.0	0.0	196.6	0.0	196.6
40	250	10.0	9999	0.0	70	0.0	0.3	0.0	0.0	166.3	0.0	166.3
41	250	13.0	9999	0.0	70	0.0	0.4	0.0	0.1	143.8	0.0	143.8
42	250	15.9	9999	0.0	70	0.1	0.5	0.0	1.5	129.6	0.0	130.3
43	250	16.2	9999	0.0	70	0.2	0.5	0.0	1.8	122.9	0.0	123.8
44	250	20.5	9999	0.0	70	1.0	0.6	0.0	14.8	93.1	0.1	100.6
45	250	22.8	9999	0.0	70	1.9	0.7	0.0	30.8	79.0	0.2	94.7
46	250	0.0	9999	5.7	70	1.5	0.2	0.0	8.7	181.9	0.1	186.4
47	250	3.3	9999	5.7	70	2.2	0.3	0.0	17.4	158.6	0.1	167.5
48	250	6.7	9999	5.7	70	2.8	0.4	0.0	28.8	137.0	0.1	151.6
49	250	10.0	9999	5.7	70	3.7	0.5	0.0	46.9	109.9	0.2	133.9
50	250	13.0	9999	5.7	70	4.5	0.6	0.0	67.2	90.0	0.4	124.4
51	250	15.9	9999	5.7	70	5.8	0.7	0.0	98.3	76.1	0.5	126.2
52	250	16.2	9999	5.7	70	5.9	0.7	0.0	100.0	71.0	1.1	123.3
53	250	20.5	9999	5.7	70	9.7	0.8	0.0	193.6	46.8	2.1	147.8
54	250	22.8	9999	5.7	70	12.7	0.9	0.1	275.2	34.1	3.2	178.0
55	250	0.0	9999	11.4	70	4.4	0.5	0.0	50.4	125.5	0.4	151.4
56	250	3.3	9999	11.4	70	5.9	0.6	0.0	81.0	104.2	0.5	145.6
57	250	6.7	9999	11.4	70	7.7	0.6	0.0	123.2	85.0	0.7	147.9
58	250	10.0	9999	11.4	70	10.3	0.7	0.0	189.7	61.2	2.0	160.0
59	250	13.0	9999	11.4	70	13.9	0.8	0.1	285.5	44.4	3.7	194.5
60	250	15.9	9999	11.4	70	16.3	0.8	0.1	367.3	36.5	3.8	227.8
61	250	16.2	9999	11.4	70	17.8	0.9	0.1	403.7	32.9	5.8	246.3
62	250	20.5	9999	11.4	70	27.7	0.9	0.2	713.9	19.2	10.6	397.3
63	250	22.8	9999	11.4	70	33.6	0.9	0.2	919.1	15.1	13.6	501.8

64	250	0.0	9999	17.1	70	10.8	0.7	0.0	184.9	76.6	2.3	173.5
65	250	3.3	9999	17.1	70	14.3	0.8	0.1	278.3	58.6	3.0	203.7
66	250	6.7	9999	17.1	70	17.4	0.8	0.1	378.1	44.6	4.3	242.2
67	250	10.0	9999	17.1	70	22.2	0.9	0.1	535.0	31.9	8.0	315.4
68	250	13.0	9999	17.1	70	29.5	0.9	0.2	773.7	21.8	11.8	432.3
69	250	15.9	9999	17.1	70	37.4	0.9	0.2	1056.3	15.6	14.3	572.4
70	250	16.2	9999	17.1	70	38.4	0.9	0.3	1091.8	14.4	15.5	591.3
71	250	20.5	9999	17.1	70	49.7	1.0	0.4	1562.3	9.1	21.8	834.0
72	250	22.8	9999	17.1	70	57.0	1.0	0.4	1882.1	8.2	25.2	999.6
73	250	0.0	9999	0.0	80	0.0	0.0	0.0	0.0	240.0	0.0	240.0
74	250	3.3	9999	0.0	80	0.0	0.1	0.0	0.0	215.3	0.0	215.3
75	250	6.7	9999	0.0	80	0.0	0.2	0.0	0.0	190.1	0.0	190.1
76	250	10.0	9999	0.0	80	0.0	0.4	0.0	0.0	155.8	0.0	155.8
77	250	13.0	9999	0.0	80	0.0	0.5	0.0	0.1	131.5	0.0	131.6
78	250	15.9	9999	0.0	80	0.2	0.5	0.0	2.1	114.2	0.0	115.3
79	250	16.2	9999	0.0	80	0.2	0.6	0.0	2.6	106.1	0.0	107.4
80	250	20.5	9999	0.0	80	1.3	0.7	0.0	22.0	72.5	0.1	83.6
81	250	22.8	9999	0.0	80	2.8	0.8	0.0	51.5	55.7	0.3	82.0
82	250	0.0	9999	5.7	80	1.5	0.2	0.0	8.7	181.9	0.1	186.4
83	250	3.3	9999	5.7	80	2.3	0.3	0.0	18.9	157.2	0.1	166.8
84	250	6.7	9999	5.7	80	2.9	0.4	0.0	32.5	132.5	0.1	148.9
85	250	10.0	9999	5.7	80	4.0	0.6	0.0	54.3	100.3	0.3	128.1
86	250	13.0	9999	5.7	80	5.1	0.7	0.0	82.1	75.8	0.8	118.4
87	250	15.9	9999	5.7	80	6.7	0.8	0.0	124.5	59.8	0.8	123.7
88	250	16.2	9999	5.7	80	6.6	0.8	0.0	123.8	57.1	1.3	121.7
89	250	20.5	9999	5.7	80	12.7	0.9	0.1	280.8	30.7	3.8	178.7
90	250	22.8	9999	5.7	80	17.3	0.9	0.1	413.4	20.2	5.6	238.0
91	250	0.0	9999	11.4	80	4.4	0.5	0.0	50.4	125.5	0.4	151.4
92	250	3.3	9999	11.4	80	6.0	0.6	0.0	83.7	101.3	0.5	144.2
93	250	6.7	9999	11.4	80	8.0	0.7	0.0	134.2	80.9	0.8	149.7
94	250	10.0	9999	11.4	80	12.0	0.8	0.0	232.8	52.8	2.9	175.0
95	250	13.0	9999	11.4	80	15.7	0.9	0.1	342.3	35.5	4.8	216.3
96	250	15.9	9999	11.4	80	20.5	0.9	0.1	495.6	26.4	5.9	286.0
97	250	16.2	9999	11.4	80	21.5	0.9	0.1	523.9	23.3	7.4	300.0
98	250	20.5	9999	11.4	80	33.0	1.0	0.2	918.0	12.0	13.4	497.9
99	250	22.8	9999	11.4	80	40.0	1.0	0.3	1184.3	8.9	17.2	635.4
100	250	0.0	9999	17.1	80	10.8	0.7	0.0	184.9	76.6	2.3	173.5
101	250	3.3	9999	17.1	80	14.3	0.8	0.0	282.6	56.6	2.9	203.7
102	250	6.7	9999	17.1	80	19.4	0.8	0.1	434.8	38.9	5.3	267.0

103	250	10.0	9999	17.1	80	22.9	0.9	0.1	573.8	28.1	7.9	330.7
104	250	13.0	9999	17.1	80	32.2	0.9	0.2	885.0	17.5	13.1	486.2
105	250	15.9	9999	17.1	80	40.5	0.9	0.3	1208.8	12.7	16.0	649.1
106	250	16.2	9999	17.1	80	43.0	1.0	0.3	1292.0	11.8	18.2	694.2
107	250	20.5	9999	17.1	80	56.6	1.0	0.4	1896.4	7.2	26.0	1007.5
108	250	22.8	9999	17.1	80	65.0	1.0	0.5	2296.3	6.2	29.6	1213.7
109	250	0.0	9999	0.0	90	0.0	0.0	0.0	0.0	240.0	0.0	240.0
110	250	3.3	9999	0.0	90	0.0	0.1	0.0	0.0	211.2	0.0	211.2
111	250	6.7	9999	0.0	90	0.0	0.2	0.0	0.0	182.9	0.0	182.9
112	250	10.0	9999	0.0	90	0.0	0.4	0.0	0.0	144.5	0.0	144.5
113	250	13.0	9999	0.0	90	0.0	0.5	0.0	0.2	116.2	0.0	116.3
114	250	15.9	9999	0.0	90	0.2	0.6	0.0	3.1	96.7	0.0	98.3
115	250	16.2	9999	0.0	90	0.3	0.6	0.0	3.8	87.8	0.0	89.7
116	250	20.5	9999	0.0	90	1.7	0.8	0.0	32.2	51.1	0.2	67.6
117	250	22.8	9999	0.0	90	4.0	0.9	0.0	81.4	34.3	0.5	76.0
118	250	0.0	9999	5.7	90	1.5	0.2	0.0	8.7	181.9	0.1	186.4
119	250	3.3	9999	5.7	90	2.2	0.4	0.0	19.3	154.6	0.1	164.3
120	250	6.7	9999	5.7	90	3.0	0.5	0.0	35.6	125.8	0.1	143.7
121	250	10.0	9999	5.7	90	4.1	0.6	0.0	59.8	90.0	0.4	120.8
122	250	13.0	9999	5.7	90	5.8	0.7	0.0	101.1	63.4	1.0	115.9
123	250	15.9	9999	5.7	90	8.0	0.8	0.0	159.7	47.0	1.1	129.1
124	250	16.2	9999	5.7	90	8.4	0.8	0.0	169.5	41.0	2.0	129.7
125	250	20.5	9999	5.7	90	17.3	0.9	0.1	418.2	18.5	6.2	240.0
126	250	22.8	9999	5.7	90	23.0	1.0	0.1	602.4	11.3	8.8	330.0
127	250	0.0	9999	11.4	90	4.4	0.5	0.0	50.4	125.5	0.4	151.4
128	250	3.3	9999	11.4	90	6.3	0.6	0.0	91.1	97.7	0.5	144.3
129	250	6.7	9999	11.4	90	8.6	0.7	0.0	150.2	72.7	1.0	149.8
130	250	10.0	9999	11.4	90	12.4	0.8	0.1	253.7	44.9	3.1	177.9
131	250	13.0	9999	11.4	90	17.3	0.9	0.1	399.8	28.1	5.8	239.5
132	250	15.9	9999	11.4	90	23.5	0.9	0.1	605.8	18.7	7.9	337.4
133	250	16.2	9999	11.4	90	24.8	0.9	0.2	645.2	17.3	9.2	358.2
134	250	20.5	9999	11.4	90	40.9	1.0	0.3	1220.1	7.2	17.9	653.0
135	250	22.8	9999	11.4	90	48.8	1.0	0.4	1557.1	5.5	22.2	828.5
136	250	0.0	9999	17.1	90	10.8	0.7	0.0	184.9	76.6	2.3	173.5
137	250	3.3	9999	17.1	90	14.6	0.8	0.0	294.0	53.0	2.9	205.8
138	250	6.7	9999	17.1	90	19.9	0.9	0.1	461.1	34.3	5.3	275.5
139	250	10.0	9999	17.1	90	25.2	0.9	0.2	658.7	21.8	9.5	370.3
140	250	13.0	9999	17.1	90	34.7	0.9	0.2	999.8	12.7	14.3	541.2
141	250	15.9	9999	17.1	90	47.3	1.0	0.3	1488.8	8.2	20.1	792.8

142	250	16.2	9999	17.1	90	48.6	1.0	0.4	1539.0	7.9	21.5	820.5
143	250	20.5	9999	17.1	90	66.1	1.0	0.5	2350.7	5.0	31.0	1242.5
144	250	22.8	9999	17.1	90	74.4	1.0	0.6	2798.2	4.1	34.4	1472.0
145	250	0.0	9999	0.0	100	0.0	0.0	0.0	0.0	240.0	0.0	240.0
146	250	3.3	9999	0.0	100	0.0	0.1	0.0	0.0	208.1	0.0	208.1
147	250	6.7	9999	0.0	100	0.0	0.3	0.0	0.0	176.6	0.0	176.6
148	250	10.0	9999	0.0	100	0.0	0.4	0.0	0.0	134.9	0.0	134.9
149	250	13.0	9999	0.0	100	0.0	0.6	0.0	0.2	103.4	0.0	103.5
150	250	15.9	9999	0.0	100	0.2	0.7	0.0	3.3	81.8	0.0	83.5
151	250	16.2	9999	0.0	100	0.2	0.7	0.0	4.0	71.3	0.0	73.3
152	250	20.5	9999	0.0	100	2.3	0.9	0.0	47.2	31.4	0.3	55.6
153	250	22.8	9999	0.0	100	6.7	0.9	0.0	151.6	15.1	1.5	93.9
154	250	0.0	9999	5.7	100	1.5	0.2	0.0	8.7	181.9	0.1	186.4
155	250	3.3	9999	5.7	100	2.2	0.4	0.0	19.7	151.4	0.1	161.4
156	250	6.7	9999	5.7	100	3.0	0.5	0.0	37.0	120.2	0.1	138.9
157	250	10.0	9999	5.7	100	4.4	0.7	0.0	69.2	78.7	0.5	114.3
158	250	13.0	9999	5.7	100	6.4	0.8	0.0	119.0	48.5	1.4	110.7
159	250	15.9	9999	5.7	100	10.1	0.9	0.0	218.8	31.4	2.0	144.8
160	250	16.2	9999	5.7	100	10.9	0.9	0.1	238.5	25.9	3.3	151.8
161	250	20.5	9999	5.7	100	22.2	1.0	0.1	580.8	8.4	8.8	316.4
162	250	22.8	9999	5.7	100	30.8	1.0	0.2	877.4	4.8	13.6	470.7
163	250	0.0	9999	11.4	100	4.4	0.5	0.0	50.4	125.5	0.4	151.4
164	250	3.3	9999	11.4	100	6.5	0.6	0.0	96.0	94.6	0.5	143.5
165	250	6.7	9999	11.4	100	9.2	0.7	0.0	166.0	66.0	1.1	151.3
166	250	10.0	9999	11.4	100	14.0	0.8	0.1	299.3	37.2	4.0	194.8
167	250	13.0	9999	11.4	100	20.0	0.9	0.1	487.0	20.6	7.1	278.4
168	250	15.9	9999	11.4	100	27.3	1.0	0.2	747.5	11.8	10.0	405.6
169	250	16.2	9999	11.4	100	29.0	1.0	0.2	800.2	10.6	11.6	433.9
170	250	20.5	9999	11.4	100	47.8	1.0	0.4	1526.2	4.1	22.0	811.1
171	250	22.8	9999	11.4	100	57.7	1.0	0.4	1970.9	2.9	26.9	1042.1
172	250	0.0	9999	17.1	100	10.8	0.7	0.0	184.9	76.6	2.3	173.5
173	250	3.3	9999	17.1	100	13.8	0.8	0.0	281.7	49.9	2.6	195.9
174	250	6.7	9999	17.1	100	20.5	0.9	0.1	487.8	30.5	5.5	285.3
175	250	10.0	9999	17.1	100	27.8	0.9	0.2	752.8	16.3	10.6	414.0
176	250	13.0	9999	17.1	100	40.1	1.0	0.3	1206.4	9.1	17.8	648.0
177	250	15.9	9999	17.1	100	52.5	1.0	0.4	1733.1	5.3	22.6	917.1
178	250	16.2	9999	17.1	100	54.6	1.0	0.4	1817.6	5.3	25.2	964.5
179	250	20.5	9999	17.1	100	75.4	1.0	0.6	2833.5	2.9	35.9	1491.4
180	250	22.8	9999	17.1	100	83.6	1.0	0.7	3334.3	2.4	39.8	1749.2

VITA

Gabriel Barron was raised in Newport, KY. Upon going to college, he earned his Bachelor's of Science in Industrial Engineering at Speed School at the University of Louisville. While at Speed School, Gabe Barron earned the Ward Award and was a member of Tau Beta Pi. For fun, he enjoys swimming laps and playing basketball. Upon earning his Master's of Engineering in Industrial Engineering, Gabe plans on marrying his beautiful fiancé and working as a Parts Commodity Engineering Specialist for Toyota.